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Twisting Neutron Waves[1]

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Most waves encountered in nature can be given a "twist", so that their phase winds around an axis parallel to the direction of wave propagation. Such waves are said to possess orbital angular momentum (OAM). For quantum particles such as photons, atoms, and electrons, this corresponds to the particle wavefunction having angular momentum of $L\hbar$ along its propagation axis. Controlled generation and detection of OAM states of photons began in the 1990s, sparking considerable interest in applications of OAM in light and matter waves[2]. OAM states of photons have found diverse applications such as broadband data multiplexing, massive quantum entanglement, optical trapping, microscopy, quantum state determination and teleportation, and interferometry. OAM states of electron beams have been used to rotate nanoparticles, determine the chirality of crystals and for magnetic microscopy. Here I discuss the first demonstration of OAM control of neutrons[3]. Using neutron interferometry with a spatially incoherent input beam, we show the addition and conservation of quantum angular momenta, entanglement between quantum path and OAM degrees of freedom. Neutronbased quantum information science heretofore limited to spin, path, and energy degrees of freedom, now has access to another quantized variable, and OAM modalities of light, x-ray, and electron beams are extended to a massive, penetrating neutral particle. The methods of neutron phase imprinting demonstrated here expand the toolbox available for development of phase-sensitive techniques of neutron imaging.

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[2]"Orbital angular momentum: origins, behavior and applications," A. *M. Yao* and *M. J. Padgett*, Adv. Opt. Photonics **3**, 161 (2011)
[3]"Controlling neutron orbital angular momentum," *C. W. Clark, et al.*, Nature **525**, 504 (2015)